Date Original Submitted: 28th October 2005
Prepared by: Wayne Landsman
Date Revised: 20th July 2006
Revision #01
Revised by:
Pages Changed:
Comments:

SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-##: TELDEF Files

0. Summary:

The telescope definition (teldef) files are used to convert between raw and detector or sky coordinates. The format of the teldef files is described in http://swiftsc.gsfc.nasa.gov/docs/swift/sdc/teldef_doc/index.htm.

1. Component Files:

FILE NAME	VALID DATE	RELEASE DATE	VER SION
swugen20041120v103.teldef	2004-11-20	2005-07-15	103
swumagni20041120v103.teldef	2004-11-20	2005-07-15	103
swugu0160_20041120v101.teldef	2004-11-20	2005-07-15	101
swugu0200_20041120v101.teldef	2004-11-20	2005-07-15	101
swugv0955_20041120v101.teldef	2004-11-20	2005-07-15	101
swugv1000_20041120v101.teldef	2004-11-20	2005-07-15	101

2. Scope of Document:

This document describes the determination of the following four quantities which are needed to create a teldef file.

(1) Boresight: This is the position in raw pixels where the target (i.e. the RA and Dec position given in the spacecraft attitude file) appears. Because of spacecraft drift, one can only calculate a mean boresight, and deviations of several arcseconds from this position are not uncommon.
(2) Detector Rotation Angle: This is the angle that the detector makes with the spacecraft roll angle given in the attitude file. It determines the angle needed to rotate a raw or detector image to North-up orientation (sky image). This angle is expected to be identical for all UVOT observing modes.
(3) Distortion Map: This is a matrix of correction vectors needed to undistort the raw image to obtain a linear plate scale. The optical fiber taper connecting the microchannel plate to the detector introduces distortions that can reach 68 pixels at the edge of the UVOT field. The distortion correction is expected to be independent of time or observing mode.
(4) Plate Scale: The scale in arc seconds/pixel in the UVOT detector and sky images. The choice of plate scale is somewhat arbitrary since the distortion map can be modified to provide any plate scale. However, the astrometric information in the header must be consistent with the chosen plate scale.

There are currently six teldef files; four for the grism modes (UV/Visible, clocked/nominal) one for the magnifier, and one for all six lenticular filters.

3. Changes

This is the first post-launch release note for the teldef files. There was an undocumented post-flight image teldef file released (Version 102) in February 2005. However, that file (based on only two post-flight images) is superceded by the current one, which combines flight data with pre-launch calibration.

4. Reason For Update:

The pre-launch teldef files needed to be calibrated to flight conditions.

5. Expected Updates:

Since the teldef file for the six lenticular filters was produced in July 2005, there have been far more extensive astrometric studies of the UVOT images. Particularly valuable for evaluating the teldef file has been the the automatic aspect correction introduced into the UVOT pipeline in December 2005, to obtain astrometry from the positions of reference stars on the image. The following updates are expected to be made to the UVOT CALDB teldef product in late 2006.

(1) Separate teldef files will be created for the six lenticular filters, which will allow for slight differences in the boresight and plate scale for the different filters. In particular, the UVW2 filter has been found to have a plate scale of 0.5043 "/pixel rather than the 0.502 "/pixel of the other filters, and the U filter has a boresight that differs by about 3" from the other filters.

(2) Different teldef files will be used depending on the mission date. In particular, the boresight for the Jan-Mar2005 timeframe appears to be different from that of later times.

(3) The mean boresight in the current teldef file is incorrect by about 5" over most of the mission. This error is normally not significant since the automatic aspect algorithm will use the positions of known reference stars in the field to correct the boresight.

(4) The detector rotation angle in the current teldef file has been found to be incorrect by about 0.026 degrees. Because the automatic aspect solution does not correct for rotation, this introduces an error in the astrometric solution of up to 1 pixel at the edge of the UVOT field.

(5) The adopted detector rotation angles for the grism nominal modes and the magnifier are incorrect by about 0.5 degrees. In the future release, all the teldef files will use the same detector rotation angle.

6. Caveat Emptor:

The previous section discusses the known limitations of the current teldef file that are expected to be improved in the subsequent release.

The distortion corrections are based on pre-launch data, and a more detailed mapping could likely now be made using flight images.

The grism teldef files do not account for the additional distortion introduced by the grism, and are not of sufficient accuracy to centroid the zeroth order given a celestial position.

7. Data Used:

ObsID	***Target***	***Date***	***Filter***	***ExpTime***
Boresight				
00055550007	PG1311+129	Feb 3, 2005	V	493
00056350002	UZFOR	Feb 2, 2005	U	5973
00067042028	M83	Feb 1, 2005	V	536
00670470029	FOCUS6	Feb 1, 2005	V	699
Rotation/Plate Scale				
00054500040	Sally's Field	Apr 15, 2005	V	2374
00103906000	GRB050128	Jan 28, 2005	V	3595
00054100001	SMCNorth	Mar 13, 2005	V	1018
00054500041	Sally's Field	Apr 15, 2005	Magnifier	1977
Grism				
00030022049	NGC 5548	Apr 26, 2005	V Grism	1026
00055050021	GD 108	Mar 15, 2005	V Grism	1167
00054001001	BPM 16274	Mar 17, 2005	V Grism	683
00055800013	Sco-X1	Apr 4, 2005	V Grism	494
00055200012	WD1057+719	May 25, 2005	U Grism	1298
00035170003	V574 Pup	May 25, 2005	U Grism	3760
00054250008	WD0320-530	May 12, 2005	U Grism	1174
00055503012	GD 153	Apr 5, 2005	U Grism	1172

8. Description of Analysis:

The raw UVOT image includes a distortion introduced by alignment variation in the optical fiber taper connecting the microchannel plate to the detector. The telescope definition (teldef) file in the pipeline both corrects for this distortion and adds astrometric parameters into the FITS header based on the telescope attitude.

(1) **Distortion Map**

The distortion was mapped during the ground-based calibration using a target mask with a grid of pinholes, and is documented in the Swift UVOT Instrument Science Report 206-R01 by Sally Hunsberger, dated March 13, 2003. The ground-based distortion map was supplied as a set of 1952 correction vectors, with the size of the correction reaching 68 pixels near the edge of the detector. In the current teldef file, the distortion vectors are mapped onto a 256 x 256 grid using thin spline smoothing. As described below, two modifications were made to the ground-based-distortion corrections.

The main change to the ground-based distortion map was that a rotation of 0.6 deg about the center of the image was applied to each displacement vector. This change was suggested by comparison of over 1500 star position (as derived from Sextractor) in the V image of the "Sally's Field" (00054500040) target in the Magellanic Clouds, with sources in the Magellanic Cloud Photometric Survey catalog (Zaritsky et al. 2002, AJ, 123, 855). If the boresight had been located at the center of the image, then this 0.6 deg rotation would simply had been incorporated into the astrometric keywords. However, the boresight position is offset from the center by about 69 pixels in the lenticular filters (see Table 1). Thus this rotation was instead applied to each of the displacement vectors in the distortion map to create a new map.

Table 1
Astrometric Parameters for the Teldef Files

Mode	***Clocking***	***CALDB File***	***Raw X***	***Raw Y***	***Scale "/pix***	***Rotation***
Image		swugen20041120v103	956	1035	0.502	-118.8
Magnifier		swumagni20041120v103	840	888	0.1259	-118.25
U Grism	200	swugu0200_20041120v101	1476	704	0.557	-118.25

Mode	*Clocking*	*CALDB File*	*Raw X*	*Raw Y*	*Scale "/pix*	*Rotation*
U Grism	160	swugu0160_20041120v101	1532	601	0.564	-118.8
V Grism	1000	swugv1000_20041120v101	1548	668	0.564	-118.25
V Grism	955	swugv0955_20041120v101	1592	537	0.564	-118.8

There is some evidence that this 0.6 deg rotation was present in the ground based calibration setup, perhaps due to an extra rotation of the pinhole mask. Figure 1 shows that the integrated displacement (the sum of all the displacement vectors) is minimized for a rotation angle of 0.6 deg.

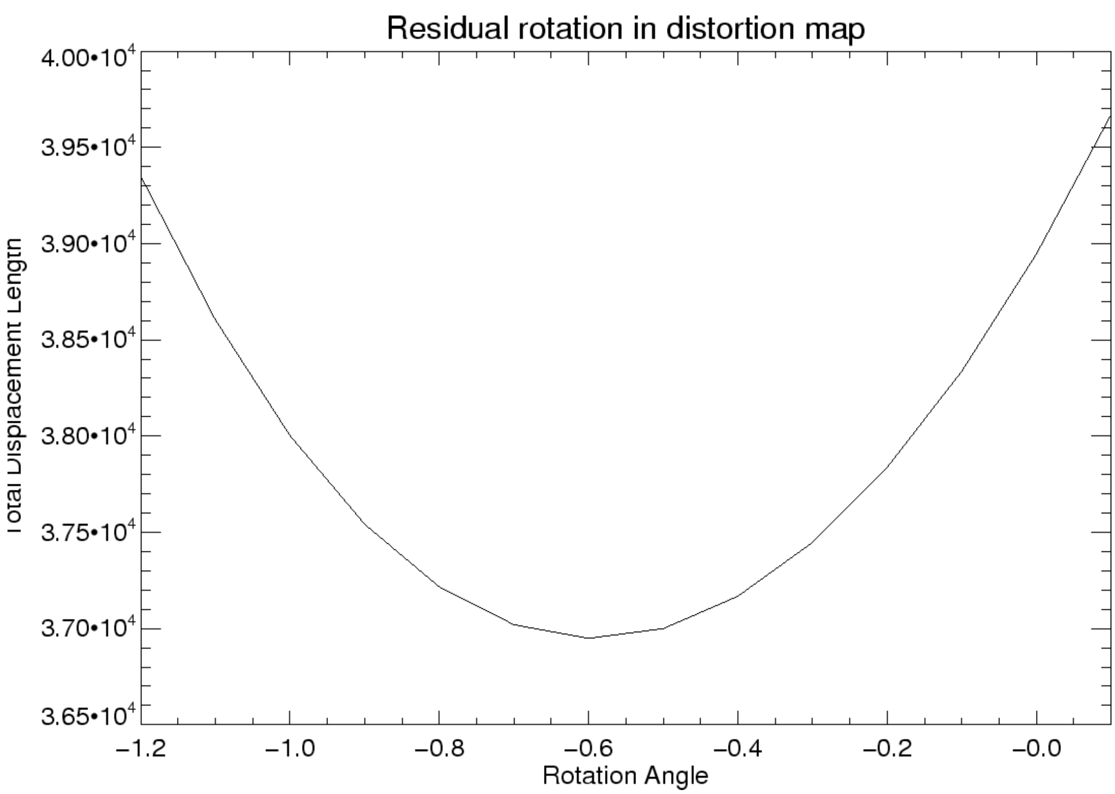

Figure 1: Total displacement as a function of rotation angle in the ground-based distortion map.

A second small change to the ground-based distortion map was to delete two of the 1952 points (listed in Table 2) which had a large discrepancy with neighboring points. Figure 2 shows that removing these two points allowed for an improved global astrometric solution, though the effect is localized to a very small area of the detector. (It is evident only in the central star in Figure 2 and a few stars below it.)

Table 2
Deleted Distortion Map Points

Old X	***Old Y***	***New X***	***New Y***
1901.47	571.68	1870.72	547.58
1942.13	592.62	1909.16	570.66

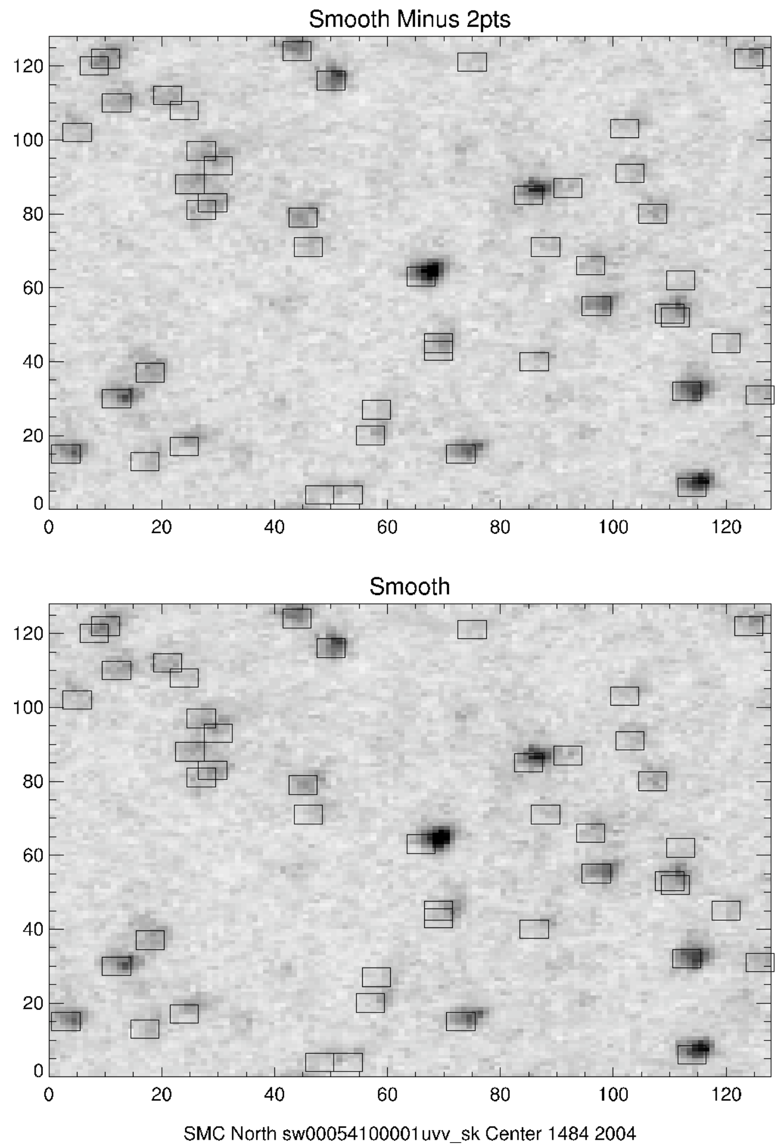

Figure 2: The effect of removing 2 deviant points from the teldef file

(2) Astrometric Parameters

1. Direct Images

All the teldef files use the same distortion map, but the boresight, plate scale and and detector rotation angle were determined using flight images (see Table 1). The boresight for the direct images was estimated in Feb 2005 by Martin Still using the following four images from Feb 1-3, 2005:

ObsID	*RA*	*Dec*	*Raw X*	*Raw Y*
00055550007	198	13	955	1035
00056460002	53	-25	960	1033
00067042028	352	59	956	1036
00067047029	7	-59	955	1035

The RawX, RawY values give the measured pixel position of the target center. The median of these values was taken to give a mean boresight at (RawX, RawY) = (956, 1035) as shown in Table 1.

The pointings listed in Section 7 were then used to derive the plate scale and detector rotation. The GSC2.2 catalog was used for the star positions except for the Magellanic Cloud pointings where the Magellanic Cloud Survey was preferred. No attempt was made to determine different astrometric parameters for different filters. The accuracy of the direct filter teldef file was assessed using a V image of the "Sally's Field" (00054500040) target in the Magellanic Clouds, where a total of 1587 sources can be matched with stars in the Magellanic Cloud Photometric Survey catalog with a mean error of 0.323".

The derived plate scale of 0.502"/pixel differs slightly from the plate scale of 0.502"/pixel measured in the ground-based calibration. The choice of a plate scale for the sky images is somewhat arbitrary because the plate scale varies across the raw image due to the distortion. It would have been possible to apply an expansion to the distortion map

2. Magnifier

The magnifier is rarely used and the astrometric parameters were derived from a single image (00054500041) of the Large Magellanic Clouds. Again, the detector angle, plate scale and boresight position were adjusted to minimize the deviations because the star centroids and positions in the Magellanic Cloud Survey. As expected, the plate scale of the magnifier (Table 1) is approximately four times smaller than in the lenticular filters. However, the rotation angle implemented in the CALDB file (-118.25 deg, Table 1) was determined before the 0.6 deg rotation of the distortion map was implemented. Thus the current CALDB magnifier teldef file gives a median error of 0.94 arcsec for 149 sources in the Magellanic Cloud field. This error would be reduced to 0.40 arcsec if the same rotation angle (-118.8 deg) used for the lenticular filter were used. This mistake will be corrected in a future CALDB release.

3. Grisms

The same method to derive the astrometric parameters for the direct images was also used for the grisms. However, the Sextractor positions cannot be directly used, because grism images consist of both zero and first (and higher) orders, and because even the zeroth order are dispersed. In addition, measurements are best done on the detector image (with a constant grism angle) rather than the sky image. Therefore a few star positions were measured manually (by centroiding the maximum pixel) on the detector image, and used to derive an astrometric solution. Two grism images were used for each grism mode (UV or V grism, clocked or nominal) so that eight images are listed in Section 7.

The accuracy of the astrometric solution for the grism is poorer with a mean error of about 1" for the nominal (unclocked) modes. A small part of this error is due to the difficulty of centroiding the zero orders, which are elongated and dependent on spectral type. However, the most likely cause appears to be additional distortion in the grism mode beyond what is given in the detector distortion map. More accurate astrometric solutions were possible for the clocked grism modes, but this may be only because the zero orders appear on a smaller area of the detector. The additional distortion in the grism images requires further investigation.